ASSESSMENT OF THE CONSEQUENCES OF A DESTRUCTIVE EARTHQUAKE AND THE NEEDS FOR RAPID RESPONSE FORCES (BY THE EXAMPLE OF ARMENIA)

***Nazaretyan S.N., **Igityan H.A., **Hakobyan H.P., **Bakunts S.H.**

**Territorial Survey for Seismic Protection of the Ministry of Internal Affairs of the Republic of Armenia, Yerevan, Armenia.*
***National Polytechnic University of Armenia, Yerevan, Armenia.*
snaznssp@mail.ru

Abstract. *In case of a seismic disaster occurring in a developing country, it is very important to determine promptly the number of possible victims and need for rescue forces to estimate the scope of required international assistance and to plan operations of rapid response forces. Rates of the seismic vulnerability of buildings, readiness of the rapid response forces, and other factors, differ from country to country and determine each country's individual capacities and effectiveness in responding to a disaster. Using the example of Armenia, general approaches are proposed for assessing losses and needs for rescue forces.*

Key words: *earthquake, losses, disaster response, needs*

Introduction

For rapid planning and organization of rescue operations and for requesting external rescue assistance, some, albeit approximate, data are needed to assess the scale of the disaster, the number of people and areas affected, the required response forces, etc. The purpose of this article is to help make an initial prompt (in a few hours) assessment of the earthquake effects and the needs for rapid response, especially rescue forces (specialists and equipment) in the event of a devastating earthquake ($7.5 \geq M \geq 7.0$).

The **main purpose** of the article is to propose an approach, which helps to determine the numbers of victims and patients subject to hospitalization approximately and to estimate the need for rescue forces within about 3 hours after a devastating earthquake.

Main results

The main outcome is related to the method of determining the consequences of an earthquake and the required rapid reaction forces, as well as the reference data for their calculation.

1.1. Important tasks and supporting indicators of the calculation

Values and objects to be determined include the following:

1. Parameters of the earthquake using seismograms to establish the time, coordinates, magnitude, depth of the hypocenter, and duration of the main event;
2. Intensity on the EMS-98 scale and based on the statistical isoseismal models of earthquake intensity distribution in the territory of the Republic of Armenia;
3. Cities located in the 8-point intensity zone, and all settlements located in the zone of intensity 9 and higher;
4. Number of possible victims and serious injuries for cities falling in the 8-point intensity zone based on the seismic risk maps, and considering the affected seismically vulnerable multi-apartment, educational and healthcare institutions;
5. Possible damage caused to infrastructure lines (transport, life support, and power supply communications) located in the 9-10-point earthquake intensity zone;
6. The required scope of rescue forces and medical staff (specialists, equipment, medical supplies and medicines) based on a tentative calculation;

7. List of medical institutions that could have become not operational, especially surgical ones, by affected settlements.

2.2. Time available for effective response.

In the territory of the Republic of Armenia, the approximate relationship between earthquake magnitude (*M*) and intensity (*Io*) is as follows: $I_0 = {}^{M}/_{2.5} + M I_0 = {}^{M}/_{2.5} + M$, or $I_0 = 1.4M I_0 = 1.4M$

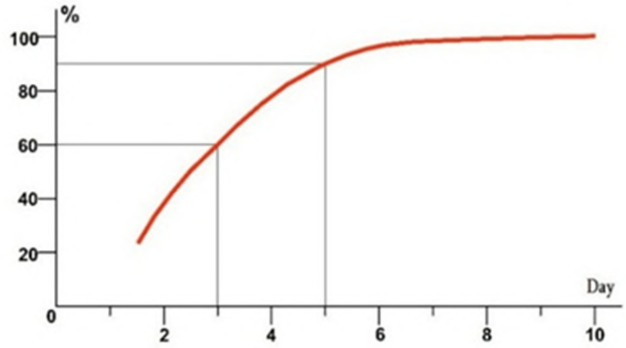

Fig. 1. Graph of the change in the percentage of irreversible losses of people trapped in the rubble during the first 10 days after a devastating earthquake [1].

2.3. Indicators to support calculation of possible casualties and serious injuries.

Depending on specific location or type of building affected [6], expected numbers of victims are estimated as follows:

A. Destroyed apartment of a residential building:

- 1.5-2.0 during the daytime, and
- 3 at night.

B. Potential random locations (shops, restaurants, markets, clubs, streets, bus stations, etc.) in the 9-point intensity zone:

- 0.5% of the total population in the daytime;
- Much smaller rates at night.

C. Private 1 or 2 story-high stone houses:

- About 0.3% and 1.0% of the total number of residents during the daytime and at night, respectively (in the case of a 9-point intensity earthquake),

D. The ratio of the number of hospitalized patients to the number of victims is 2.0-3.0.

2.4. Dependence of the average damage rate values on the earthquake intensity for different types of residential buildings

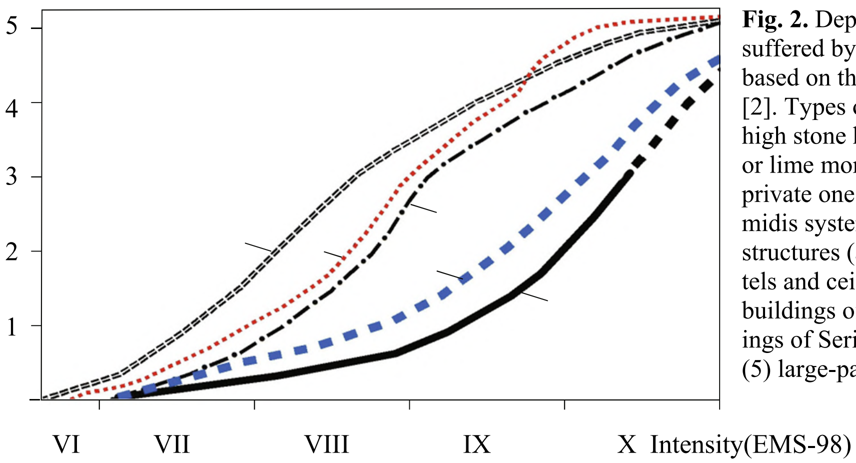

Fig. 2. Dependence of the average rates of damage suffered by different types of residential buildings based on the intensity of the 1988 Spitak earthquake [2]. Types of buildings: (1) private one to two story-high stone houses of the midis system with sand–clay or lime mortar without use of metal elements; (2) private one or two story-high stone houses of the midis system with cement mortar and use of metal structures (antiseismic belts, reinforced concrete lintels and ceilings, etc.); (3) frame-type apartment buildings of Series 111, 4–12 floors; (4) stone buildings of Series IA-450 or I-451, with 4 or 5 floors; and (5) large-panel apartment buildings with 4 to 9 floors.

Table1. The main structural types of multi-apartment buildings in Armenia, their brief description [7], the level of seismic vulnerability of buildings located in a seismic zone with an intensity of 9 points for Category 2 soils [5].

Nₒ.	Structural type of buildings	Number of floors	Construction period	Brief Description of the Design	Rates of Seismic vulnerability
1	Stone, built by individual project	3–6, (4 floors)	Before 1958	Masonry of the *midis* type (stones laid on both sides of wall and lime mortar with crushed stone filled in between). Walls were 60 cm thick; wooden floors, concrete stairs	Medium
2	Stone, Series I-451	4–5	1958–1970	Midis-type walls were used, wall thickness corresponded to 50cm, cement mortar. Factory-made (precast) hollow panels of concrete. Antiseismic belts were built between the floors and around the ceilings.	Medium
3	Stone, Series IA-450	4–5	From early in 1970 to early in 1988	Midis-type walls 50 cm thick with cement mortar. Factory-made (precast) concrete hollow panels. Antiseismic belts were built between the floors and around the ceilings. The walls were reinforced with vertical reinforced concrete elements.	High
4	Frame-panel, Series111	9	1975–1988	The bearing reinforced-concrete frame was applied in the longitudinal direction. Columns and structural panels (wall) were built in the transverse direction. The columns were sized 40×40 cm. Factory-made hollow panels were used.	High
5	Built by the method of floor lifting	12 or 16	1970–1988	Solid-core walls and factory-made columns with solid floor panels. Floor panels were lifted into the correct position up along the columns.	High
6	Frame-bonded types of design by Badalyan and Manukyan	Badalyan type had 12 (10) or 14 (18) floors; Manukyan type had (10) floors	1960–1988	Factory-made (precast) reinforced-concrete frames were applied for both types. The columns were sized 50×50cm. It was estimated that buildings of this type were more resistant than those of the frame-panel type, taking into account the position of the reinforcement joints. The Manukyan-type column had the size of 40×40 cm. Note: There were no buildings of these types in the area of the Spitak earthquake in1988.	Medium
7	Large-panel, Series 1-451КП	9 or 5	1970–the present	Factory-made (precast) walls, reinforced-concrete structure	Low
8	Monolithic, reinforced-concrete Bearing frame	4 floors or higher	1989 and after 1994	The load-bearing frame is made of monolithic reinforced concrete, including the walls. The design was based on the 1994 RA seismic standards. Non-bearing walls are built of light-weight concrete blocks..	Low

Note: Low-vulnerability buildings have damage degrees of 1-2 and, according to the current RA building codes, can be operated. Buildings with **medium** rate of vulnerability suffer 3rd degree damage mainly, and their safe operation will no longer be guaranteed; hence, these buildings are subject to reinforcement. **Highly** vulnerable buildings are damaged at the rate of 4-5 degrees, and if they are not important as historical and architectural monuments, it is more economical to demolish them.

Table 2. Estimates of potential damage caused to the RA infrastructure lines (life support, transport, communication) falling within earthquake intensity zones of 8-10 points [1,4].

Infrastructure	Rates of Damage by Earthquake Intensity		
	8 points	9 points	9–10 points
Water supply lines	Low	Medium	Strong
High-voltage power supply lines	Low	Medium	Strong
High-pressure gas supply lines	Low	Strong	Strong
Cable telecommunication lines	Low	Strong	Strong
Railways	Low	Weak	Strong
Highways	Low	Weak	Strong

Indicators to support calculation of the required rescue forces

Some estimates of the rescue efforts are provided below.

3.1. Required fire-rescue forces.

For the territory of the Republic of Armenia, it is necessary to use the following data for the 1988 Spitak earthquake [1,3]:

- The scope of rescue forces is estimated at about 38,000 rescuers and 3,150 units of heavy rescue equipment. The required staff of professional rescuers is estimated at 900. This scope would be sufficient number for a destruction zone with a population of about 1,000,000;
- Firefighters carried out about 1,500 missions during the first 10 days.

3.2. Required medical care.

- The number of medical workers who provided timely medical care to 40,000 seriously ill patients was estimated at 5,000.
- During the first 5 days after the earthquake, they performed about 60,000 operations. Each surgeon performed up to 5-8 operations per day.
- The amount of drugs and medical supplies used for 5,000 hospitalized patients is provided in [6].

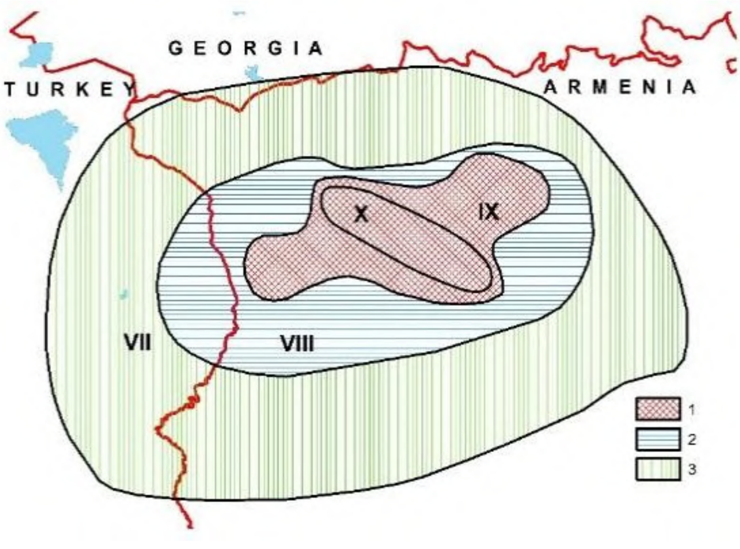

Fig. 2. Schematic map demonstrating the zones of potential damage of buildings and the factors of the impact on human health as a result of the 1988 Spitak earthquake [5]: 1 – the main zone of building damage related to the 4th and 5th degrees (earthquake intensity of IX–X points) and possible victims and heavy injuries; 2 – the zone of building damage related to the 3rd degree (intensity of VIII points) and wounded patients with minor injuries; 3 – the zone of minor building damage (intensity of VII points) and deterioration of living conditions of the population.

Conclusion

This article presents general approaches and some indicators to support preliminary calculations of possible losses and required rapid response forces as soon as 2-3 hours after a devastating earthquake ($7.5 \geq M \geq 7.0$) occurs in Armenia or in adjacent areas. They are extremely important for: a) planning and organizing rescue and medical assistance to the victims; b) determining the need to request international assistance. The approach can serve as an example for carrying out similar work in different countries.

Acknowledgments

The work was financed from the state budget of the RA within the framework of a comprehensive program to reduce seismic risk in the territory of the Republic of Armenia and the Higher Education and Science Committee of MESCS RA (Research project № 25RG-1E115).

References

1. Nazaretyan S.N., The Seismic Hazard and Risk of territories of cities located in the zone of 1988 Spitak earthquake. (Editor- Dr., Prof. Darbinyan S.). // Publ. house Gitutiun- Sciences of National Academy of Sciences of Armenia, Yerevan, 2013, 205 p. (in Russian), ISBN: 978-5-8080-0999-8
2. Nazaretyan S.N. ,Main features of the new methodology for seismic risk assessment of Armenian cities//Seismic Instruments, USA, vol. 56,2020: 317-331. https://doi.org/10.3103/S0747923920030093
3. Nazaretyan S.N., Nazaretyan S.S., Assessment of the Need for Rescue Forces during Destructive Earthquakes (a Case Study of Armenia) // Seismic Instruments, USA, Vol.57, N 2, 2021:150-162, Doi.org/10.3103/S0747923921020298
4. Nazaretyan S.N. and Igityan H.A., Possible Environmental Impact of a Destructive Earthquake // Izvestiya, Atmospheric and Oceanic Physics, Vol. 58, Suppl. 1, 2022: S79-S92. Doi: 10.1134/S0001433822130072
5. Nazaretyan S.N., Gevorgyan M.R., Igityan H.A., Mirziyan L.B., Mughnetsyan E.A., Dynamics of Time Changes in the Seismic Risk of a Big City Due to the Vulnerability of Apartment Buildings(a Case Study of Yerevan) // Izvestiya, Atmospheric and Oceanic Physics, v. 58, No. 8, 2022: 867–880. DOI:10.1134/S0001433822080023
6. Nazaretyan S.N., Haroutiunian R.A., Impact of a Destructive Earthquake on People's Life and Health // Seismic Instruments, USA, Vol. 60, No. 4–6, 2024: 80–92. 2024. DOI:10.3103/S0747923925700136
7. The project for seismic risk assessment and risk management planning in the Republic of Armenia: Final Report JICA, 2012, p. 245. https://openjicareport.jica.go.jp/pdf/12086054_01.pdf.